

V. MEASURED EFFECTS AND IMPACT OF PLANT OPERATIONS ON COMMERCIALLY IMPORTANT BENTHIC RESOURCES

Three commercially important benthic organisms (the American oyster, the soft-shell clam, and the blue crab) inhabit the Calvert Cliffs region of the Chesapeake Bay. Studies to assess the effects of power plant operations on all three species were conducted by other investigators and/or organizations (Table 1). This chapter only summarizes their major findings. The conclusions and/or interpretations of other investigators were generally accepted as long as they were based on reasonable data collection and analysis procedures. Appendix C has a brief discussion of the data collection and analysis procedures used. For details of methods on these studies, see the original publications listed in Table 1. Occasionally (e.g., for oyster growth studies), independent analyses were made of some of the data available in reports to ensure that similar conclusions would be reached by a different analysis approach.

A brief review of the life cycle and commercial importance of each species is presented prior to discussing effects of power plant operations on them. The intent of this review is to provide insight into the modes of interaction between each species and plant operations.

A. American Oysters

Because the Calvert Cliffs plant site is not a major oyster producing area, plant operations could not have any significant impact on oyster production of the Chesapeake Bay. However, plant operations did enrich oysters in the immediate discharge region with copper. Copper levels in oysters from this area were high enough (100 mg/kg wet weight of tissue) to cause oyster tissues to be green in color and bitter tasting.

Growth of tray-held oysters was significantly higher ($P < 0.05$) at the plant site than it was at reference locations. Plant operations did not have any effects on the meat condition or mortality of tray-held oysters.

The American oyster is one of the most sought-after benthic resources in the Chesapeake Bay. In recent times, the Chesapeake Bay harvest of oysters has been between 20 and 30% of the total oyster harvest of the United States. The volume of the Maryland oyster fishery is about two-thirds of the Bay fishery and has an annual dockside value in excess of 10 million dollars. The value of the processed meat exceeds 50 million dollars (Meritt, 1977; Haven et al., 1978).

The oyster has a relatively complex life cycle. Like many benthic organisms, eggs are released into the plankton and fertilization occurs in the water (e.g., Galtstoff, 1964). Planktonic development proceeds through two larval stages (trochophore and veliger) and lasts from two to six weeks. At the completion of their planktonic development, oyster larvae migrate to the bottom to search for a suitable substrate on which to metamorphose into juveniles (called spat).

American oysters can live under a wide range of environmental conditions (e.g., they can tolerate salinities from 5 to 35 ppt). However, their best growth and reproduction occurs in the mesohaline regions of estuaries (8-15 ppt), including the Chesapeake Bay. In these areas, they are relatively free from their less salinity tolerant predators and/or parasites, and have good growth and successful reproduction. During their planktonic life stages, oysters are particularly sensitive to adverse environmental conditions (e.g., low dissolved oxygen, poor water quality, and food supply).

Oysters were commercially harvested in the Calvert Cliffs area of the Chesapeake Bay (Flag Pond oyster bar) prior to construction of the power plant. During the construction phase, a major portion of a natural oyster bar in the discharge area was transplanted to the Patuxent estuary (Fig. 6). Only isolated populations of oysters presently inhabit the immediate vicinity of the plant, and their densities are well below commercially exploitable levels. In 1975 and 1976, the Fisheries Division of the Maryland Department of Natural Resources contracted to have over 150,000 bushels of oyster shell deposited at three locations just south of the plant (Fig. 6). Fisheries personnel planned to use these shells to restore the Flag Pond oyster bar as a commercial oystering site.

Because the Calvert Cliffs region has not been a particularly good region of the Bay for oyster recruitment, entrainment of planktonic stages

of oysters would not be likely to influence oyster recruitment in the Bay. Therefore, studies of entrainment effects on oyster larvae were not conducted. If oyster larvae attempted to settle in the immediate discharge area, they could be subjected to scour and mechanical damage. Even though they probably experienced limited recruitment success in the scoured area, oyster spat occurred there in 1976 and 1978; and in our March 1976 survey, there were as many spat in the scoured area as there were in other oyster producing areas of the Calvert Cliffs region (Holland et al., 1977b). The effects of power plant operations on planktonic stages of oysters are probably insignificant.

Oysters are reported to be bioaccumulators of heavy metals, particularly copper (Roosenberg, 1969; Huggett et al., 1973). Copper levels in discharge waters are significantly higher ($P < 0.05$) than copper levels in intake waters (e.g., Harris, 1979). Because there is great natural variation in the levels of metals in oysters (e.g., Pringle et al., 1968), it would be difficult to separate power-plant related increases in copper levels from naturally occurring high levels just by measuring levels in oysters (O'Connor, 1976). In fact, before plant operations began, levels in tray-held oysters were higher at the plant site than they were at the reference areas (Abbe, 1979b).

One method that can be used to overcome the problem of high natural variation in copper levels is to investigate the ratio of copper levels to that of some geochemically similar metal whose source is not power plant cooling water and whose chemical behavior in animal tissue is assumed to be similar (e.g., zinc). Because fluctuations in zinc levels should be almost entirely due to natural processes, and because zinc and copper naturally occur in similar ratios in particular sediment types, investigations of the copper to zinc ratio in oysters, in a sense, take into account natural variation in metal levels and processes controlling them (O'Connor, 1976). Changes in the copper/zinc ratio with distance from power plant discharges should thus be a good indicator of the power plant contribution to copper levels in oysters.

The copper to zinc ratio in oyster tissues of the Calvert Cliffs region was not studied during the preoperational period. During one-unit operations, copper to zinc ratios were similar at the plant site and a reference area.

After two-unit operations began, the copper to zinc ratio in oysters was significantly higher ($P < 0.05$) at the plant site than it was at reference areas (Phelps, 1977). At copper levels above 100 mg/kg wet weight of tissue, oyster tissue is green, bitter tasting, and not fit for human consumption. This level was occasionally exceeded at the discharge site during two-unit operations, but not at reference areas. Copper levels in oyster tissue decreased with increasing distance from the point of discharge. The size of the region where oysters were enriched by copper was limited but not defined (Abbe, 1979b). Although power plant operations have resulted in copper enrichment to oyster populations in the immediate discharge region, it has not had any significant impact on oyster harvests in the Chesapeake Bay. Not only was the size of the affected area small, but oyster bars at the plant site have never been a significant commercial source of oysters.

Oyster growth as well as survival is dependent on temperature, an environmental variable that is influenced by plant operations. In addition to controlling the onset of spawning, temperature affects the development rate and survival of eggs and larvae. Growth of tray-held oysters was often significantly higher ($P < 0.05$) at the plant site than it was at reference areas (e.g., Abbe, 1978a, 1979a). The Academy of Natural Sciences of Philadelphia's preoperational oyster growth data were also modeled, and then the observed and predicted growth rates were compared during the operational period (Martin Marietta, 1977) by calculating a percentage difference (Table 17). A nonparametric analysis of variance (Friedman two-way analysis of variance) applied to the percentage difference in oyster growth among stations indicated that oyster growth was significantly different ($P < 0.05$) among stations after operations began. The percentage difference between predicted and observed values was higher at the plant site than it was at reference areas. The increase in oyster growth at the plant site could be the result of the slightly higher temperatures that occur there during optimum growth periods (i.e., fall) and/or the higher levels of suspended organic material (i.e., food) that are available for consumption (see previous section on sediment trap studies).

B. Soft-shell Clams

Plant operations resulted in increased growth and recruitment of soft-shell clams in the discharge region. This caused the production of clams to be higher in the vicinity of the plant than it was at reference areas during much of the operational period. Growth and recruitment of soft-shell clams was not higher at the plant site before operations began.

Even though plant operations have affected growth in soft-shell clam populations in the Calvert Cliffs region, we concluded that plant operations had little impact on clam harvests of the Bay, because commercially harvestable densities did not historically, nor do they now, occur in the Calvert Cliffs area.

Soft-shell clams were probably commercially harvested from the Chesapeake Bay in Colonial times. But, after the hydraulic clam dredge, which could collect the deep-burrowing, market-size clams in commercial quantities, was developed in the 1950's, many more soft-shell clams were harvested throughout much of the Chesapeake Bay. Peak harvests were made in the mid 1960's. Since 1967, soft-shell clam populations have declined to extremely low levels, and in recent years, very few clams have been taken from the Bay. Reasons for the declining harvests of soft-shell clams are not clear (Lippson et al., 1979). Hurricane Agnes, poorer water quality, and over-fishing have all been suggested as contributing causes (Lippson et al., 1979).

Soft-shell clams, Mya arenaria, inhabit a wide range of substrate types from soft muds to firm, hard-packed sands. They are generally most abundant on firm-sand or muddy-sand bottoms at depths of 4-6 m (Lippson et al., 1979). This species is generally considered to be a filter-feeder. However, because M. arenaria primarily draws water from the layer nearest the sediment-water interface, many of the filtered and ingested particles are probably resuspended material.

M. arenaria can tolerate salinities from 3-35 ppt, and commercially harvestable quantities are generally limited to salinities above 8 ppt (Pfitzenmeyer and Droebeek, 1963). Soft-shell clams in the Calvert Cliffs region spawn twice a year -- once in spring and once in fall (Pfitzenmeyer,

1962). Embryonic stages are planktonic, and recruitment success varies from year-to-year with a strong recruitment occurring every 10-15 years (Haven, 1976). Recruitment is generally more successful in fall than in spring (Appendix B).

Because samples collected in benthic community studies contained large numbers of juvenile Mya arenaria, they could be used to determine the effects of plant operations on soft-shell clam productivity (Appendix C). Since production estimates are a good means of determining the amount of biomass produced by an exploitable population that is available to be harvested, production estimates of M. arenaria were calculated during all years when benthic community data were collected.

The length of the largest soft-shell clam obtained by benthic community studies at Calvert Cliffs was 29 mm. However, M. arenaria can grow to 40 mm in one year in this region of the Bay (Hanks, 1968). Apparently, our collection methods did not adequately sample older age classes (i.e., larger individuals). Siphons of large clams were frequently collected in samples, indicating they were present but had burrowed too deep to be sampled. Estimates of growth and production are thus limited to the first yearclass. However, the first yearclass should be a good indicator of power plant effects because it generally composes up to 85% of a population just after setting (Burke and Mann, 1974). Furthermore, small soft-shell clams are more susceptible to environmental fluctuations than are larger ones (Matthiessen, 1960).

Soft-shell clams were about the same size at the plant site and at reference areas during the preoperational period. During the operational periods, those at the plant site were larger than clams at reference areas (Table 18). These findings indicate that clams grew at a faster rate at the plant site than at the reference areas after operations began. The higher growth rate observed at the plant site could be the result of the slightly higher temperatures and higher organic input (i.e., food for clams).

Abundances of M. arenaria were only occasionally higher at the plant site than at reference areas during the preoperational period. After plant operations began, the abundance of M. arenaria immediately following recruitment was frequently larger near the plant site than it was at

reference areas (Tables D-7 through D-18; Tables 23, 28, and 34 in Holland et al., 1978). The previously discussed higher settlement rates of benthic larvae in the vicinity of the plant could explain the higher near-plant abundances. When the planktonic larvae of soft-shell clams are about to settle and take up a benthic existence, they may find the portion of the nearfield region that is organically enriched from entrainment mortalities (see previous discussion on sediment trap studies) to be a more favorable habitat than reference areas because of the large quantities of food available.

Figure 40 presents production estimates of soft-shell clams for each year at all sampling sites. The greatest production occurred along the 6- to 7-m depth contours, and the least at deeper and shallower depths. During the preoperational period, production of soft-shell clams was generally about the same or higher at reference areas than at the plant site. After plant operations began, soft-shell clam production was consistently higher at the plant site than it was at reference locations, and in 1976 and 1977, production of Mya arenaria was two to three times higher at the plant site than it was at northern or southern reference areas.

During the preoperational period, average densities of market-size soft-shell clams near Calvert Cliffs ranged from 98 to 172 liters per hectare (ANSP, 1972d, 1973a; Abbe, 1974a, 1975a). These densities are below levels required to make commercial harvesting economically feasible. Thus, although soft-shell clams may, at times, be dominant members of the macrobenthic community, they cannot be considered an important commercial resource of the Calvert Cliffs region. In addition, the temporal instability of their populations and their isolated nature in the Calvert Cliffs region would seem to indicate that commercial harvesting would not be economical in the near future.

Studies to assess the effects of entrainment on planktonic stages of M. arenaria, including the effects on settling rates, are currently being conducted by Ecological Analysts, Inc. for Baltimore Gas and Electric Company (Table 1). Results of these studies were still being evaluated when this report was prepared.

C. Blue Crabs

Power plant operations have not affected the abundance, sex ratio, or size of blue crabs in the Calvert Cliffs region. Even though large numbers of blue crabs were impinged annually, mortalities from this stress were small. Plant operations have thus had no substantial adverse effects on blue crab populations at Calvert Cliffs or any impact on blue crab harvests in the Chesapeake Bay.

The blue crab, Callinectes sapidus, is the most sought-after crustacean in the Maryland portion of the Chesapeake Bay. Commercial and recreational crabbers harvest millions of crabs per year. The harvest of crabs is exceeded only by that of oysters in terms of landing value in the region of the Bay from the Bay Bridge to the Virginia border. In recent years, annual commercial landings have frequently exceeded 6,000 metric tons and approached a value of two million dollars (National Marine Fisheries Service, 1977, 1978). An extensive sports fishery also exists for crabs, the value of which has never been estimated, but probably exceeds that of the commercial fishery. Both commercial and recreational crabbing occurs in the Calvert Cliffs region of the Bay.

Blue crabs are omnivorous and feed on other benthic invertebrates, small fish, aquatic vegetation with its associated fauna, and dead vegetation. They, in turn, are preyed upon by large fish, birds, and, of course, by man. They have a complex life cycle that involves relatively elaborate courtship and mating behavior and long migrations. Although courtship and mating occurs in the Maryland portion of the Bay, planktonic stages are only spawned at the mouth of the Bay in higher salinity waters (e.g., Van Engle, 1958). A larva will remain in the plankton for about six weeks, after which it metamorphoses into a small crab-like stage, which over a period of several weeks changes into a juvenile crab. Juvenile crabs migrate up the Chesapeake Bay and all its tributaries.

The activity and behavior of blue crabs vary with seasonal changes in water temperature. In spring, as water temperatures begin to increase, blue crabs become active. Juvenile crabs and mature males that buried themselves superficially the sediments of the deep channel areas during winter, migrate upstream and toward shore. Juveniles added to the population in

the lower Chesapeake Bay spawning grounds during the previous fall begin arriving at Calvert Cliffs in spring (Sulkin, 1973). Throughout the summer and warm fall months, blue crabs primarily inhabit shallow nearshore waters. As water temperatures begin to decrease at the end of fall, mature females migrate out of the Calvert Cliffs region to the spawning grounds in the lower Chesapeake Bay. Some of the remaining juvenile crabs and mature males move into deeper channel areas where they overwinter. A few blue crabs may stay in shallow areas until October or November, but at the first abrupt drop in temperatures, they also move into deeper channel areas and settle into the bottom muds for the winter.

Blue crab abundance has fluctuated from year-to-year in the Calvert Cliffs region (Abbe, 1979c). However, no significant ($P < 0.05$) plant site-reference area differences in the number of crabs collected in crab pots were observed between the preoperational and operational periods (Abbe, 1979c). Female crabs caught at the southern reference area were significantly ($P < 0.05$) heavier than female crabs caught at the plant site or the northern reference area during both the preoperational and operational periods (e.g., Abbe, 1978c, 1979c). Otherwise, there were no differences in the sizes (shell width or weight) of blue crabs at various stations, before or during the operational period (Abbe, 1979c).

Significantly more ($P < 0.05$) male crabs occurred at the northern reference area than at the plant site or southern reference area during the preoperational period. However, there were no significant differences in the female to male ratio of crabs among stations during the operational period (Abbe, 1979c).

Very few planktonic stages of blue crabs occurred as far up the Bay as Calvert Cliffs. Juveniles were the youngest life stage abundant in the plant area. When they reached the plant site, a few of these juvenile crabs were only 4 or 5 mm wide across the back, but most were about 1 cm (Sulkin, 1973). At this size, they would not easily pass through the screens (~ 1-cm mesh) protecting the cooling water intake structure, particularly since their appendages extend well beyond the width of the back. Thus, entrainment of crabs at Calvert Cliffs is minimal. However, these juvenile crabs, like the adults, can be impinged on the traveling screens. About 300,000 to 500,000 juvenile and adult crabs were impinged

annually between 1975 and 1978. Crabs were about 55% of the weight and 18% of the number of all impinged organisms (Hixon and White, 1979).

The numbers of crabs impinged varied seasonally. Greatest numbers were taken in early summer and late fall with about twice as many female crabs impinged as males (Hixon and White, 1979). However, at the same time, male crabs comprised over 50% of the crab pot catches (Abbe, 1979c). Because the highest numbers of crabs were impinged at times when blue crabs, particularly females, were making major migrations up and down the Bay, it appears that there is some interaction between migrating individuals and the plant.

Although large numbers of crabs were impinged, they suffered negligible mortality (less than 1%) from this stress (Burton, 1976). Crabs on the intake screens feed on impinged fish, and it has been speculated that the rate of the crab impingement might reflect the attractiveness of the screens as a feeding site. It has also been suggested that the crabs in the vicinity of the plant are recycled -- being impinged, washed back into the Bay, and then reimpinged. No data have been obtained to corroborate these speculations.

Both adult and juvenile crabs were exposed to increased temperatures and current velocities in the discharge area. The extent of the thermal stress to which they were exposed depended on their residence time in the plume. However, temperatures in the thermal plume were well within the tolerance limits of blue crabs. In addition, because of the relatively high discharge velocities, plume exposure time would probably be minimal since blue crabs would be swept from the areas of highest temperatures by currents. Since blue crabs are omnivorous, it is unlikely that the power plant would disturb the crab food chain, especially since there is as much, if not more food available at the plant site than in other regions of the Calvert Cliffs area.

A major concern expressed during the construction phase was that the heated effluent of the plant would cause overwintering crabs burrowed in the Bay bottom to become active during colder seasons. No such effect was evident. Very few blue crabs were taken in winter trawls conducted at the plant site, and when crabs were collected during colder months, just as many crabs were collected at reference areas (Wilson et al., 1979).

VI. TABLES AND FIGURES

Table 1. List of benthic studies that have been conducted at the Calvert Cliffs power plant, and a summary of the types of data obtained, sampling history, organizations conducting and funding studies, and references where detailed information on each study can be found.

Study	Parameters Measured	Sampling Methods	Sampling location	Sampling Frequency	Period of Data Collection	Organization Conducting Study *	Sponsoring Agency	Publications Prepared
Benthic community studies	Salinity, temperature, dissolved oxygen, sediment characteristics, numbers and types of microbenthic organisms, macrobenthic community biomass, and productivity of dominant clam species	Samples collected with anchor dredge, hydraulic grab, or diver-collected cores sieved on 1.0- and 0.5-mm screens	40 stations throughout Calvert Cliffs region	Quarterly	1971-1977	E/CBL	PPSP/DOE	Milbrathy, 1972; Mountford et al., 1973, 1974, 1976, 1977b; Holland et al., 1977a, 1977b, 1978; Holland, 1976
Macrofaunal density		Samples collected with a Smith-McIntyre grab and sieved a 0.5-mm screen	15 stations throughout Calvert Cliffs region	Six times per year	1977-1979	ANSF	BCGE	Ioi, 1979
Benthic metabolism study	Salinity, temperature, dissolved oxygen profiles, water column respiration and production, benthic respiration, chemical oxygen demand of sediments	Gores of hydraulic grab samples sieved on a 63- μ m screen	14 stations throughout Calvert Cliffs region	Once	Summer 1978	E/CBL	PPSP	This report
Fish stomach contents studies		Vertical measurements of physical parameters, light and dark bottle oxygen evolution and utilization, monitoring oxygen decrease under a dome located on the bottom with and without formalin	Plant site and reference station north of the plant site	Quarterly	1976-1978	CBL	PPSP	Boynton et al., 1978a, 1978b
Stomachs of fish collected by trawl; contents were removed and examined		Calvert Cliffs area		Monthly		ANSF	BCGE	Moore, 1973
Stomachs of fish collected by trawl; contents were removed and examined		Plant site and reference stations		Approximately bi-monthly		CBL	PPSP	Flower and Boynton, 1978

* ANSP - Academy of Natural Sciences of Philadelphia

BCGE - Baltimore Gas and Electric Company

CBL - Chesapeake Biological Laboratory of the University of Maryland

DOE - Department of Energy (formerly Energy Research and Development Agency)

HC - Environmental Center of Martin Marietta Corporation

PAI - Ecological Analysts, Incorporated

NASA - National Aeronautical and Space Administration

PPSP - Power Plant Siting Program of Maryland Department of Natural Resources

UDC - University of the District of Columbia

Table 1. Continued

Study	Parameters Measured	Sampling Methods	Sampling Location	Sampling Frequency	Period of Data Collection	Organization Conducting Study	Sponsoring Agency	Publications Prepared
Shallow water surveys	Numbers and kinds of flora and fauna including benthic organisms	Nets, scrapers, dredges, scines, and tongs	Plant site and reference areas north and south of the plant	Twice per summer	1968-present	ANSPL	BGE	ANSPL, 1969a, 1970a, 1972a, 1972b, 1973a, 1974a
Oyster studies	a. Oyster tray studies Length, width, meat condition, and mortality of oysters; fouling organisms occurring with oysters	Trays containing oysters were suspended in the water; oysters were collected at random and appropriate measurements made	Plant site and reference areas north and south of the plant	Quarterly	1970-1978	ANSPL	BGE	ANSPL, 1972c, 1972f, 1974b; Abbe, 1975b, 1975e, 1976a, 1976d, 1977a, 1978a, 1979a
b. Oyster spat survey	Numbers of juvenile oysters and quantity of shell	Oyster dredge	Calvert Cliffs region	March	1977	EC/CBL	PPSP	Ko Lland et al., 1978
c. Oyster bar surveys	Oyster density	Oyster dredge	Oyster bars at the plant site and in reference areas	Irregularly	1968-present	ANSPL	BGE	ANSPL, 1968; Abbe and Hart, 1975
d. Heavy metals in oysters	Levels of heavy metals in oysters	Dredge samples of oysters	Calvert Cliffs area	Quarterly	1974-1977	UDC	NASA	Phelps, 1977
Soft-shell clam studies	a. Soft-shell clam surveys	Abundance of market-size soft-shell clams	Trays containing oysters were suspended in the water; oysters were collected periodically and levels of heavy metals in tissues determined	Plant site and reference area	1973-present	ANSPL	BGE	Abbe, 1975c, 1975f, 1976b, 1976e, 1977b, 1978b, 1979b
			Commercial clamming dredge	Calvert Cliffs area	Annually	1972-present	ANSPL	BGE
								ANSPL, 1972d, 1973b; Abbe, 1974a, 1975a

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CBL - Chesapeake Biological Laboratory of the University of Maryland

DDE - Department of Energy (formerly Energy Research and Development Agency)

EC - Environmental Center of Martin Marietta Corporation

MAI - Ecological Analysts, Incorporated

NASA - National Aeronautical and Space Administration

PPSP - Power Plant Siting Program

Resources

UC - University of the District of Columbia

Table 1. Continued

Study	Parameters Measured	Sampling Methods	Sampling Location	Sampling Frequency	Period of Data Collection	Organization Conducting Study*	Sponsoring Agency	Publications Prepared
Soft-shell clam studies (cont.)								
b. Soft-shell clam entrainment	Soft-shell clam larval density	Larval table with 220 μm mesh	Intake water	Weekly during spawning season	1979	EAI	BGE	EAI, 1979
c. Recruitment of soft-shell clams	Abundance of juvenile soft-shell clams	Bottle collectors	Plant site and reference locations north and south of the plant	Biweekly during spring & fall setting period	1979	ANSP	BGE	Abbe, 1979d
d. Production of soft-shell clams	Size, weight, and abundance of soft-shell clams	Anchor dredge and hydraulic grab sampler	21 stations throughout the Calvert Cliffs region	Quarterly	1971-1978	CBL/IC	PPSP	Mantour et al., 1976; this report
Blue crab studies								
a. Crab pot studies	Sex, weight, size, and abundance of blue crabs	Commercial crab pots (5 per station)	Plant site and reference areas north and south of the plant site	May-Nov	1967-present	ANSP	BGE	ANSI, 1969b, 1970b, 1971, 1972c, 1973c; Abbe, 1974 b, 1975d, 1975g, 1976c, 1976f, 1977c, 1978c, 1979c
b. Blue crab impingement studies	Sex, weight, size, and abundance of impinged blue crabs	Crabs were collected from intake screen wash and appropriate measurements made	Intake screens	162 hours per day, 5 to 6 days per week	1975-present	ANSP	BGE	Abore, 1977; Naiven et al., 1978a; Nixon and White, 1979
c. Mortality of impinged blue crabs	Survival of impinged blue crabs	Crabs collected from screen wash trough and held in tanks and mortality noted	Intake screens	Spring to late fall	1975	ANSP	BGE	Burton, 1976

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IC - Environmental Center of Martin Marietta Corporation

EAI - Ecological Analysis, Incorporated
 NASA - National Aeronautical and Space Administration
 PPSP - Power Plant Siting Program of Maryland Department of Natural Resources
 UIC - University of the District of Columbia

Table 1. Continued

Study	Parameters Measured	Sampling Methods	Sampling Location	Sampling Frequency	Period of Data Collection	Organization Conducting Study*	Sponsoring Agency	Publications Prepared
Blue crab studies (cont.)	d. Abundance of blue crabs in bottom trawls	Sex, weight, size, and relative abundance of blue crabs in bottom trawls	Bottom trawls	Plant site and reference areas north and south of the plant site	Approximately monthly	1977-1978	CBL & ANSP	PPSP & BGGE Wilson et al., 1979; Naiman et al., 1978; Nixon and Lipizzi, 1979

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 BGGE - Baltimore Gas and Electric Company
 CBL - Chesapeake Biological Laboratory of the University of Maryland
 DOE - Department of Energy (formerly Energy Research and Development Agency)
 EC - Environmental Center of Martin Marietta Corporation

EAI - Ecological Analysts Incorporated
 NASA - National Aeronautical and Space Administration
 PPSP - Power Plant Siting Program of Maryland Department of Natural Resources
 UDC - University of the District of Columbia

Table 2. Summary of site characteristics and design characteristics of the Calvert Cliffs nuclear power plant.

Physical Characteristics of the Plant Site

Salinity Regime	Mesohaline
Width of Bay at Calvert Cliffs	10 km
Tidal excursion distance	5-6 km
Annual range of ambient water temperatures	0-27°C

Plant Design Features

Generating capacity

1 Unit	850 MWe
2 Units	1700 MWe

Amount of Bay water used for cooling

1 Unit	$76 \text{ m}^3 \text{ sec}^{-1}$
2 Units	$152 \text{ m}^3 \text{ sec}^{-1}$

Condenser ΔT

-5.5°C

Biofouling Control

Amertap

Intake system

Curtain wall extending 9 m below the surface of the water

1300 m-long intake channel (~ 15 m deep)

Intake embayment with removable panels

Traveling screens

Discharge system

Discharge conduit extending offshore to 3-m depth contour (~ 260 m)

Submerged jet

400 m-long dredged discharge channel (~6 m deep)

Table 3. Modes of interaction between benthic organisms and the Calvert Cliffs power plant and possible consequences of interactions.

Life Stage	Direct Interaction	Type of Stress	Possible Consequence to Organism	Possible Consequence to Population
Eggs and larvae	Entrainment (passage through cooling system)	Mechanical and physiological	Mortality, physiological or morphological impairment (e.g., greater vulnerability to predation), and redistribution (offshore species may be redistributed into nearshore waters)	Increase or decrease in the number of eggs or larvae settling in the nearfield region (dependent upon localization of spawning and number of larvae in intake waters), which could change densities of adult stocks near the plant site
	Plume entrainment (mixing with discharge waters)	Mechanical and physiological	Mortality, physiological or morphological impairment (e.g., mechanical damage occurs when larvae attempt to settle in regions that have high velocity currents), and redistribution (transport of eggs and larvae into offshore areas where survival may be higher or lower)	Increase or decrease the number of eggs or larvae settling in the nearfield region dependent upon localization of spawning and the number of larvae subjected to plume entrainment), which could change densities of adult stocks near the plant site
Juveniles and adults	Entrainment of motile species Impingement on intake screens and entrapment in intake embayment	Mechanical and physiological	Mortality, abrasion (e.g., loss of appendages), physiological impairment (e.g., weakened organism, not able to withstand natural stresses of estuarine environment), and redistribution Mortality, abrasion (e.g., loss of appendages), and physiological impairment (e.g., weakened organism, not able to withstand natural stresses of estuarine environment)	Increase or decrease in local populations (dependent on population distributions), which could change the structure of benthic communities at the plant site Increase or decrease in local populations (dependent on population distributions), which could change the structure of benthic communities at the plant site

Table 3. Continued

Life Stage	Direct Interaction	Type of Stress	Possible Consequence to Organism	Possible Consequence to Population
Juveniles and adults (Cont.)	Exposure to elevated temperatures and high velocity currents in the plume	Mechanical and physiological	Mortality, abrasion, and change in physiological condition (e.g., change in the timing of reproduction) of organisms in the plume area	Increase or decrease in local stocks, which could change the structure of benthic communities near the plant site

Table 4. Summary of general characteristics of macrobenthic communities inhabiting the scoured area, a preoperational-period shell habitat, and an operational-period shell habitat during spring.

	Scoured Area Macrobenthic Community (May 1977) (May 1978)	Preoperational Period Shell Habitat Macrobenthic Community (May 1972)	Operational Period Shell Habitat Macrobenthic Community (May 1977)
Number of species	24	26	28
Number of epifaunal species	8	8	6
Percent of fauna composed of species characteristic of shell habitats	74	77	4

Table 5. Summary of species abundances in the scoured area, in a preoperational-period shell habitat, and in an operational-period shell habitat sampled during spring.

Cluster Group	Species Name	Mean Number of Individuals/Square Meter	Percent of Total Abundance	Frequency of Occurrence in Samples
Scoured Zone Macrofaunal Community (May 1977)	<i>Balanus</i> spp.*	3236.0	23.6	100.0
	<i>Ceropagis lacustris</i> *	7384.0	50.3	100.0
	<i>Dicidiumenae laevis</i> *	5084.0	14.0	100.0
	<i>Veretis succinea</i>	4258.0	11.7	100.0
	<i>Melita nitida</i> *	3046.0	8.4	100.0
	<i>Polydora ligni</i> *	3026.0	9.3	100.0
	<i>Mya arenaria</i>	1752.0	4.8	100.0
	<i>Macoma balthica</i>	794.0	2.2	100.0
	<i>Heteromastus filiformis</i>	760.0	2.1	100.0
	<i>Streblospio benedicti</i>	688.0	1.9	100.0
	<i>Scolecolepides viridis</i>	556.0	1.5	100.0
	<i>Brachiodontes recurvus</i> *	290.0	0.8	100.0
	<i>Oligochaetes</i>	168.0	0.5	100.0
	<i>Stylococcus ellipticus</i> *	144.0	0.4	100.0
	<i>Stenope helopoda</i>	128.0	0.4	100.0
	<i>Diporella obscura</i>	14.0	0.0	100.0
	<i>Amphura mucronatus</i>	12.0	0.0	75.0
	<i>Crassostrea virginica</i> *	10.0	0.0	50.0
	<i>Nucula leddyi</i>	10.0	0.0	75.0
	<i>Pectinaria gouldii</i>	6.0	0.0	25.0
	<i>Macoma phasma</i>	4.0	0.0	25.0
	<i>Mytilus edulis</i> *	2.0	0.0	25.0
	Gastropod Species C	2.0	0.0	25.0
	<i>Monoculodes schardti</i>	2.0	0.0	25.0
TOTALS		56366.0		
Preoperational- Period Shell Habitat, Macrofaunal Community (May 1972)	<i>Mya arenaria</i>	6388.7	50.0	100.0
	<i>Macoma balthica</i>	1743.0	13.7	100.0
	<i>Amphura lateralis</i>	1707.2	13.4	100.0
	<i>Veretis succinea</i>	964.9	7.6	100.0
	<i>Dicidiumenae laevis</i> *	497.9	3.9	100.0
	<i>Scolecolepides robusta</i>	484.2	3.8	87.5
	<i>Scolecolepides viridis</i>	328.7	2.6	100.0
	<i>Haplocoleolites fragilis</i>	267.2	2.1	100.0
	<i>Paraprioposio pinnata</i>	118.0	0.9	50.0
	<i>Nucula leddyi</i>	72.9	0.6	100.0
	<i>Brachiodontes recurvus</i> *	50.5	0.4	62.5
	<i>Pectinaria gouldii</i>	35.4	0.3	87.5
	<i>Stenope lactea</i>	29.8	0.2	75.0
	<i>Edoras triloba</i>	21.0	0.2	62.5
	<i>Macoma phasma</i>	15.5	0.1	87.5
	<i>Balanus</i> spp.*	10.9	0.1	37.5
	<i>Acastostra concolorata</i>	9.9	0.1	25.0
	<i>Glycindis solitaria</i>	4.8	0.0	37.5
	<i>Glycera diaphanata</i>	4.5	0.0	62.5
	<i>Crassostrea virginica</i> *	3.8	0.0	25.0
	<i>Heteromastus filiformis</i>	2.1	0.0	37.5
	<i>Monoculodes schardti</i>	2.1	0.0	25.0
	<i>Stylococcus ellipticus</i>	1.9	0.0	25.0
	<i>Ceropagis lacustris</i> *	1.5	0.0	25.0
	<i>Melita nitida</i> *	1.1	0.0	12.5
	<i>Callianassa septemtaenia</i>	1.1	0.0	12.5
	<i>Zyphura polita</i>	0.8	0.0	12.5
	<i>Leptocheirus pilularius</i>	0.3	0.0	12.5
TOTALS		12767.6		
Operational- Period Shell Habitat, Macrofaunal Community (May 1977)	<i>Scolecolepides viridis</i>	53792.0	39.4	100.0
	<i>Mya arenaria</i>	3754.0	5.7	100.0
	<i>Macoma balthica</i>	1732.0	2.6	100.0
	<i>Ceropagis lacustris</i> *	432.0	0.7	100.0
	<i>Veretis succinea</i>	238.0	0.4	100.0
	<i>Balanus</i> spp.*	180.0	0.3	75.0
	<i>Heteromastus filiformis</i>	130.0	0.2	100.0
	<i>Stenope helopoda</i>	100.0	0.2	100.0
	<i>Streblospio benedicti</i>	84.0	0.1	100.0
	<i>Amphura mucronatus</i>	80.0	0.1	25.0
	<i>Nucula leddyi</i>	54.0	0.1	100.0
	<i>Dicidiumenae laevis</i>	42.0	0.1	100.0
	<i>Macoma phasma</i>	26.0	0.0	100.0
	<i>Acastostra</i> spp.	16.0	0.0	25.0
	<i>Neomya americana</i>	16.0	0.0	25.0
	<i>Polydora ligni</i> *	16.0	0.0	75.0
	<i>Melita nitida</i> *	12.0	0.0	100.0
	<i>Glycindis solitaria</i>	9.0	0.0	100.0
	<i>Oligochaetes</i>	6.0	0.0	25.0
	<i>Amphura lateralis</i>	4.0	0.0	50.0
	<i>Leptocheirus pilularius</i>	4.0	0.0	25.0
TOTALS		65736.0		

* Indicates epifaunal species.

Table 6. Summary of power plant effects on macrobenthic community characteristics during summer.

Community Characteristics	H A B I T A T	9- to 10-m Depth Contours
Number of species	No apparent effect. ¹ About the same number of species occurred in samples collected from the plant site and reference areas during the preoperational and operational periods (Fig. 15).	No apparent effect. During most summers, macrobenthic communities throughout the study area were stressed naturally by near anoxic conditions. The effects of anoxic conditions on macrobenthic organisms obscured any effects of power plant operations (Fig. 17).
Number of individuals	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Fig. 18).	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Fig. 19).
Biomass	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Table 8).	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Table 9).
Abundance and rank by abundance of numerically dominant species	No apparent effect. The abundance and rank by abundance of numerically dominant species was as different between northern and southern reference areas as it was between reference areas and nearfield sampling sites during the preoperational and operational periods, making the detection of power plant effects on this community characteristic unlikely (Table D-7, and Table 17 in Holland et al., 1978).	No apparent effect. The abundance and rank by abundance of numerically dominant species was as different between northern and southern reference areas as it was between reference areas and nearfield sample sites during the preoperational and operational periods, making the detection of power plant effects on this community characteristic unlikely (Table D-8, and Table 19 in Holland et al., 1978).

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 6. Continued

Community Characteristics	H A B I T A T	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Community structure (i.e., discriminant score)	No significant effect. ² Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (e.g., Figs. 25 and 26 in Holland et al., 1978).	No significant effect. The structure of macrobenthic communities at northern and southern reference areas were as different from each other as they were from those in the nearfield area during the preoperational and operational periods. This station-to-station variation in community structure was probably related to the heterogeneous distribution of sediments and the intense predation characteristic of this habitat.	No significant effect. During most summers, macrobenthic communities throughout the study area were stressed naturally by near anoxic conditions. The effects of anoxic conditions on macrobenthic organisms obscured any effects of power plant operations.
Community function (i.e., benthic respiration)	No significant effect (Table 3 in Boynton et al., 1978b).	No significant effect (Table 3 in Boynton et al., 1978b).	Not measured.

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 7. Summary of power plant effects on macrobenthic community characteristics during fall.

Community Characteristics	Habitat	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Number of species	No apparent effect. ¹ About the same number of species occurred in the samples collected from the plant site and from reference areas during the preoperational and operational periods (Fig. 21).	No apparent effect. Slightly more species occurred in samples from the plant site during both the preoperational and operational periods (Fig. 22).		After the power plant began operating, slightly more species occurred at one station near the plant site (P-III) than occurred at reference areas. A similar pattern was not observed during the preoperational period. Power plant operations appear to have modified sediment characteristics at this station, so it became colonized by more species of macrobenthic organisms than found in reference areas (Fig. 23).
Number of individuals	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Fig. 24).	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Fig. 25).		After the power plant began operating, densities of macrobenthic organisms were significantly higher at one station (P-III) near the plant than they were at reference areas. A similar pattern was not observed during the preoperational period. Power plant operations appear to have modified sediment characteristics at this station, so it could support higher densities of macrobenthic organisms (Fig. 26).
Biomass	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Table 8).	No apparent effect. Bottom-feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (Table 9).		After the power plant began operating, higher macrobenthic biomass occurred at sample sites near the plant than at reference areas. A similar pattern was not observed during the preoperational period. Power plant operations appear to have modified sediment characteristics at some nearfield stations, so they could support larger macrobenthic standing stocks than they did before plant operations began (Table 10).

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 7. Continued

Community Characteristics	HABITAT		
	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Abundance and rank by abundance of numerically dominant species	No apparent effect. The abundance and rank by abundance of numerically dominant species was as different between northern and southern reference areas as it was between reference areas and nearfield sample sites during the preoperational and operational periods, making detection of power plant effects on this community characteristic unlikely (Table D-10, and Table 21 in Holland et al., 1978).	No apparent effect. The abundance and rank by abundance of numerically dominant species was as different between northern and southern reference areas as it was between reference areas and nearfield sample sites during the preoperational and operational periods, making detection of power plant effects on this community characteristic unlikely (Table D-11 and Table 23 in Holland et al., 1978).	After the power plant began operating, abundances of some numerically dominant species were higher in the near field region than they were at reference areas. A similar pattern was not observed during the preoperational period (Table H-12, and Table 24 in Holland et al., 1978).
Community structure (i.e., discriminant score)	No significant effect. ² Bottom feeding predators cropped macrobenthic stocks to comparable low levels near the plant and at reference areas. The effects of predators on macrobenthic standing stocks obscured any effects of power plant operations (e.g., Figs. 34 and 35 in Holland et al., 1978).	No significant effect. The structure of macrobenthic communities at northern and southern reference areas were as different from each other as they were from those in the nearfield area during the preoperational and operational periods. This station-to-station variation in community structure was probably related to the heterogeneous spatial distribution of sediments and the intense predation characteristic of this habitat.	The structure of macrobenthic communities at some nearfield stations was significantly different from the structure of macrobenthic communities at reference areas (e.g., Fig. 41 in Holland et al., 1978). A similar condition was not observed during the preoperational period. This appears to be related to power-plant-induced modifications of substrate characteristics that occur in this habitat.
Community function (i.e., benthic respiration)	No significant effect (Table 3 in Boynton et al., 1978b).	No significant effect (Table 3 in Boynton et al., 1978b).	Not measured.

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 8. Summary of biomass data (ash-free dry weight per m^2 in grams) collected at benthic sampling stations along the 2- to 3-m depth contours. Blank spaces indicate that samples have not been processed.

Season	St.-1	WS-1/1	LB-1/4	FP-1	Station				GS-1	RP-1/13
					CCO-1/6	7	CCU-1/8	CCV-1/10		
Winter										
1971	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled
1972	2.538	Not sampled	1.332	0.476	1.291	Not sampled	Not sampled	Not sampled	Not sampled	0.466
1973	0.303	Not sampled	0.749	0.563	0.298	Not sampled	Not sampled	Not sampled	Not sampled	0.133
1974	0.699	0.954	0.601	18.051	0.579	Not sampled	Not sampled	1.216	1.163	0.877
1975										
1976										
1977	Not sampled									
1978	Not sampled	0.607	0.838	Samples lost	Samples lost	0.611	0.735	0.581	0.602	
Spring										
1971	0.252	Not sampled	0.730	1.820	0.287	Not sampled	Not sampled	0.463	0.411	
1972	1.821	Not sampled	0.809	2.228	1.627	Not sampled	Not sampled	0.785	1.882	
1973	3.152	Not sampled	2.649	1.265	3.606	Not sampled	Not sampled	3.693	1.185	
1974	3.612	2.359	1.967	35.594	1.371	Not sampled	1.035	1.629	1.325	
1975										
1976										
1977	Not sampled									
1978	Not sampled	3.420	1.965	5.567	1.838	1.472	1.962	1.201	1.043	
Summer										
1971	0.247	Not sampled	0.457	0.316	0.888	Not sampled	Not sampled	0.451	0.219	
1972	2.004	Not sampled	1.059	1.372	0.290	Not sampled	Not sampled	1.567	1.968	
1973	0.681	Not sampled	1.643	0.908	2.482	Not sampled	Not sampled	1.146	0.651	
1974	1.435	3.108	1.109	1.041	3.022	Not sampled	3.335	5.516	0.885	
1975										
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	0.978	1.495	0.765	1.708	2.549	1.835	1.111	1.730	
Fall										
1971	0.980	Not sampled	1.013	0.434	0.668	Not sampled	Not sampled	0.889	0.372	
1972	4.967	Not sampled	2.182	1.384	0.570	Not sampled	Not sampled	17.542	1.740	
1973	0.666	Not sampled	0.469	1.684	0.650	Not sampled	Not sampled	1.004	0.845	
1974										
1975										
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	1.488	0.825	0.733	0.676	0.269	0.868	2.061	0.525	

Table 9. Summary of biomass data (ash-free dry weight per m^2 in grams) collected at benthic sampling stations along the 6- to 7-m depth contours. Blank spaces indicate that samples have not been processed.

Season	St. 11	WS- 11/2	LB- 11/5	FP- 11	CCO- 11	S t a t i o n			CCS- 11	RP- 11
						15	15	CC1-11/9		
Winter										
1971	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled
1972	33.421	Not sampled	3.368	0.920	23.992	Not sampled	Not sampled	Not sampled	4.846	3.716
1973	0.961	Not sampled	1.285	7.360	13.484	Not sampled	Not sampled	Not sampled	0.807	1.862
1974	7.691	11.410	1.242	18.125	2.865	Not sampled	4.846	2.131	0.549	
1975						Not sampled				
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	1.126	0.686	Samples lost	Samples lost	8.965	0.998	0.754	0.644	
Spring										
1971	0.123	Not sampled	1.248	54.023	4.101	Not sampled	Not sampled	1.441	0.410	
1972	62.815	Not sampled	5.599	10.868	17.464	Not sampled	Not sampled	46.392	8.018	
1973	6.037	Not sampled	4.194	38.990	11.156	Not sampled	Not sampled	5.499	12.934	
1974	13.308	12.650	9.015	20.031	11.041	Not sampled	10.611	8.294	3.913	
1975						Not sampled				
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	3.943	6.870	24.176	5.813	Last samples	7.569	2.262	1.060	
Summer										
1971	0.868	Not sampled	0.896	8.176	4.126	Not sampled	Not sampled	1.826	0.446	
1972	10.686	Not sampled	13.125	9.181	9.921	Not sampled	Not sampled	9.280	4.087	
1973	16.501	Not sampled	12.461	20.557	3.516	Not sampled	Not sampled	17.135	9.281	
1974	19.280	8.904	19.272	12.041	7.411	Not sampled	4.906	31.930	23.429	
1975						Not sampled				
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	2.560	1.036	2.125	2.615	10.665	1.079	2.135	0.919	
Fall										
1971	5.093	Not sampled	1.717	0.641	3.398	Not sampled	Not sampled	2.803	2.210	
1972	1.180	Not sampled	1.313	31.009	18.120	Not sampled	Not sampled	1.636	1.043	
1973	1.318	10.852	0.775	4.420	1.189	Not sampled	0.787	3.905	0.719	
1974						Not sampled				
1975						Not sampled				
1976	Not sampled									
1977	Not sampled									
1978	Not sampled	1.677	0.872	1.803	0.650	16.091	1.813	1.405	0.875	

Table 10. Summary of biomass data (ash-free dry weight per m^2 in grams) collected at benthic sampling stations along the 9- to 10-m depth contours. Blank spaces indicate that samples have not been processed.

Season	S t a t i o n						RP-111
	SC-111	WS-111/3	LB-111	FD-111	CCO-111	CC1-111/10	
Winter 1971	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled	Not sampled
1972	1.244	Not sampled	1.162	1.268	6.973	Not sampled	1.062
1973	2.080	Not sampled	1.254	1.099	1.587	Not sampled	0.666
1974	0.723	1.219	0.913	1.246	0.989	1.353	1.302
1975						0.196	1.676
1976	Not sampled						0.360
1977	Not sampled						
1978	Not sampled	0.667	0.455	Samples lost	0.211	0.636	0.620
							0.487
Spring							
1971	4.470	Not sampled	4.377	1.050	0.270	Not sampled	0.455
1972	2.703	Not sampled	2.759	3.368	3.207	Not sampled	2.411
1973	2.270	Not sampled	1.570	0.967	8.740	Not sampled	9.251
1974	3.368	2.060	1.868	1.850	1.656	2.831	3.340
1975							1.221
1976	Not sampled						
1977	Not sampled						
1978	Not sampled	1.669	1.106	3.145	1.198	1.962	0.458
							0.509
Summer							
1971	5.282	Not sampled	0.960	0.032	0.030	Not sampled	0.021
1972	0.981	Not sampled	0.064	0.045	1.355	Not sampled	0.025
1973	0.444	Not sampled	0.117	0.015	0.256	Not sampled	0.007
1974	0.618	0.497	0.443	0.232	0.593	0.672	0.004
1975							0.319
1976	Not sampled						
1977	Not sampled						
1978	Not sampled	0.123	0.103	0.175	0.321	0.273	0.107
							0.064
Fall							
1971	0.974	Not sampled	1.086	1.288	1.769	Not sampled	0.753
1972	0.802	Not sampled	0.232	0.111	0.174	Not sampled	0.741
1973	0.664	0.767	0.209	0.205	0.351	0.951	0.310
1974							
1975							
1976	Not sampled						
1977	Not sampled						
1978	Not sampled	0.622	0.331	1.826	0.607	0.981	0.201
							0.193

Table 11. Summary of power plant effects on macrobenthic community characteristics during winter.

Community Characteristics	H A B I T A T	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Number of species	No apparent effect. ¹ About the same number of species occurred in samples collected from the plant site as occurred in samples collected from reference areas during the preoperational and operational periods (Fig. 27).	No apparent effect. Slightly more species occurred in samples from the plant site during both the preoperational and operational periods (Fig. 28).	After the power plant began operating, slightly more species were collected near the plant site than were collected at reference areas. A similar pattern was not observed during the preoperational period (Fig. 29). Power plant operations appear to have modified sediment characteristics in part of the nearfield region, so it became colonized by more kinds of macrobenthic organisms than reference areas.	
Number of individuals	Benthic densities of macrobenthic organisms were lower at some sites near the plant than they were at reference areas during some operational years. Lower densities were not observed at the plant site during the preoperational period (Fig. 30).	No apparent effect. About the same number of macrobenthic organisms occurred in samples collected from the plant site and reference areas during the preoperational and operational periods (Fig. 31).	After the power plant began operating, densities of macrobenthic organisms were significantly higher at nearfield sampling areas (particularly Station FP-II) than they were at reference areas. A similar condition was not observed during the preoperational period. Power plant operations appear to have modified sediment characteristics in the nearfield region, resulting in the higher numbers of benthic organisms occurring there (Fig. 32).	
Biomass	No apparent effect. Benthic biomass was generally similar at reference and nearfield areas during the preoperational and operational periods. Station-to-station variation in benthic biomass was related to sediment characteristics, with the highest biomass values generally occurring in the sandiest sediments (Table 9).	No apparent effect. Benthic biomass was generally similar at northern reference and nearfield areas during the preoperational and operational periods. Station-to-station variation in benthic biomass was related to sediment characteristics, with the highest biomass values generally occurring in the plant site (Table 10).	No apparent effect. Microbenthic biomass was generally similar at reference and nearfield areas, even though the number of macrobenthic organisms was higher near the plant site. The higher densities at the plant site were due to juvenile specimens that did not constitute much biomass (Table 10).	After the power plant began operating, microbenthic biomass densities of some macrobenthic organisms were higher at the plant site than they were at reference areas. A similar condition was not observed during the preoperational period (Table D-14, and Table 28 in Holland et al., 1978).
Abundance and rank by abundance of numerically dominant species	No apparent effect. The abundance and rank by abundance of numerically dominant species were as different between northern and southern reference areas as they were between reference areas and nearfield sample sites during the preoperational and operational periods, making the detection of power plant effects on this community characteristic unlikely (Table D-13, and Table 26 in Holland et al., 1978).			After the power plant began operating, densities of some macrobenthic species were slightly higher at the plant site than they were at reference areas. A similar condition was not observed during the preoperational period (Table D-15, and Table 30 in Holland et al., 1978).

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 11. Continued

Community Characteristics	HABITAT		
	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Community structure (i.e., discriminant score)	<p>During some winters after the power plant been operating, the structure of macrobenthic communities at some nearfield stations was significantly different from the structure of macrobenthic communities at reference areas (e.g., Fig. 45 in Holland et al., 1978). A similar condition was not observed during the preoperational period.</p>	<p>No significant effect.² The structure of macrobenthic communities at northern and southern reference areas were as different from each other as they were from the structure of macrobenthic communities in the nearfield region during the preoperational and operational periods. This station-to-station variation in community structure was probably related to the heterogeneous spatial distribution of sediments characteristic of this habitat (e.g., Fig. 5) in Holland et al., 1978).</p>	<p>After the power plant began operating, the structure of macrobenthic communities at nearfield stations, particularly those located north of the discharge site, was significantly different from the structure of macrobenthic communities at reference locations (e.g., Figs. 55 and 56 in Holland et al., 1978). A similar condition was not observed during the preoperational period.</p>
Community function (i.e., benthic respiration)	<p>No significant effect (Table 3 in Boynton et al., 1978b).</p>	<p>No significant effect (Table 3 in Boynton et al., 1978b).</p>	<p>Not measured.</p>

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 12. Summary of power plant effects on benthic community characteristics during spring.

Community Characteristics	H A B I T A T	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Number of species	No apparent effect. ¹ About the same number of species occurred in plant site samples as occurred in reference area samples during the preoperational and operational periods (Fig. 33).	No apparent effect. Slightly more species occurred in plant site samples than occurred in reference area samples during the preoperational and operational periods (Fig. 34).	After power plant operations began, slightly more species were collected near the plant site than were collected at reference areas. A similar pattern was not observed during the operational period (Fig. 35). Power plant operations appear to have modified sediment characteristics in some of the nearfield region, so it could become colonized by more kinds of macrobenthic organisms than found in reference areas.
Number of individuals	Benthic densities of macrobenthic organisms were higher at some sites near the plant than they were at reference areas during some operational years. Higher densities were not observed at the plant site during the preoperational period (Fig. 36).	No apparent effect. Sampling sites near the plant had higher densities than the reference area during both the preoperational and operational periods (Fig. 37).	After power plant operations began, densities of macrobenthic organisms were significantly higher at some nearfield areas. Higher densities were not observed at the plant site during the preoperational period. Power plant operations appear to have modified sediment characteristics in the nearfield region, resulting in higher densities of some macrobenthic organisms (Fig. 38).
Biomass	No apparent effect. Macrofaunal biomass was generally similar at reference and nearfield areas during the preoperational and operational periods (Table 9), even though the number of macrobenthic organisms was higher at the plant site after operations began. The higher densities at the plant site were due to juvenile specimens that did not constitute much biomass.	No apparent effect. Macrofaunal biomass was generally similar at reference and nearfield areas during the preoperational and operational periods (Table 10), even though the number of macrobenthic organisms was higher at the plant site after operations began. The higher densities at the plant site were due to juvenile specimens that did not constitute much biomass.	Macrofaunal biomass was higher at the plant site stations (particularly FP-III) than it was at reference-area stations during the operational period. Higher standing stocks were not observed at the plant site during the preoperational period (Table 11).
Abundance and rank by abundance of numerically dominant species	During some operational years, densities of the polychaete, <i>Scolecolepides viridis</i> , were significantly higher in samples collected at nearfield Station 8 than they were in samples collected at reference areas. Higher densities of <i>S. viridis</i> were not observed at the plant site during the preoperational period (e.g., Table D-16, and Table 32 in Holland et al., 1978).	During some operational years, densities of the polychaete, <i>Scolecolepides viridis</i> , were significantly higher in samples collected at the nearfield station than they were in samples collected at reference areas. Higher densities of <i>S. viridis</i> were not observed at the plant site during the preoperational period (e.g., Table D-17, and Table 34 in Holland et al., 1978).	After plant operations began, densities of some species were higher in samples collected near the plant site than they were in samples collected at reference areas. Higher densities were not observed at the plant site during the preoperational period (e.g., Table D-18, and Table 36 in Holland et al., 1978).

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 12. Continued

Community Characteristics	HABITAT		
	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
Community structure (i.e., discriminant score)	The structure of macrobenthic communities at nearfield stations with higher than reference area densities of <i>Scuticociliates viridis</i> after plant operations began, were significantly different.	No significant effect. ² The structure of macrobenthic communities at northern and southern reference areas were as different from each other as they were from the structure of macrobenthic communities in the nearfield area during the preoperational and operational periods. This station-to-station variation in community structure was probably related to the heterogeneous spatial distribution of sediments characteristic of this habitat (e.g., Fig. 51 in Ibiland et al., 1978).	The structure of macrobenthic communities at near-field stations, particularly those located North of the discharge site, was significantly different from the structure of macrobenthic communities at reference locations after power plant operations began. A similar condition was not observed during the preoperational period (e.g., Figs. 55 and 56 in Ibiland et al., 1978).
Community function (i.e., benthic respiration)	No significant effect (Table 3 in Boynton et al., 1978b).	Not measured	

¹ "No apparent effect" indicates that for the community characteristic being evaluated, there were no differences between reference-area and nearfield sample sites that could be attributed to plant operations. In some cases, quantitative differences, even statistically significant ones, may have existed. However, differences between the nearfield and reference areas were of a similar magnitude during the preoperational period, suggesting that operational-period differences were due to natural causes (e.g., patchiness) and not plant operations.

² "No significant effect" indicates that a specific statistical test was performed and there were no significant differences ($P < 0.05$) between reference areas and nearfield sample sites that could be attributed to plant operations. Such analyses were only performed when the community attribute being evaluated was similar at reference areas and plant-site stations during the preoperational period.

Table 13. Summary of the seasonal and annual effects of power plant operations on benthic communities.

	2- to 3-m Depth Contours	6- to 7-m Depth Contours	9- to 10-m Depth Contours
	H A B I T A T	H A B I T A T	H A B I T A T
Summer	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.
Fall	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	Balances of some fall spawning species were higher at the plant site than they were at reference areas after plant operations began. This difference was statistically significant and was attributed to plant operations.
Winter	Balances of one species of polychaete worm were lower at one nearfield station than at reference areas after plant operations began. This difference was statistically significant and was attributed to plant operations.	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	Balances of several fall and winter spawning species were higher near the plant site than they were at reference areas after plant operations began. This difference was statistically significant and was attributed to plant operations.
Spring	Balances of some spring spawners were higher at the plant site than they were at reference areas after plant operations began. This difference was statistically significant and was attributed to plant operations.	Balances of some spring spawners appeared to be higher in the nearfield region than at reference areas after plant operations began. At this time, we are not certain how much of this difference is due to plant operations and how much to natural causes.	Balances of several fall and winter spawning species were higher near the plant site than they were at reference areas after plant operations began. This difference was statistically significant and was attributed to plant operations.
Annual	No long-lasting, plant-related changes in macrobenthic communities.	No differences in macrobenthic communities near the plant site and at reference areas that could be attributed to plant operations.	Recruitment of some late fall through spring spawners was higher at the plant site than at reference areas. This trend resulted in significantly higher winter through spring standing stocks of some macrobenthic species at the plant site and was attributed to plant operations.

Table 14. Summary of information obtained from recruitment traps along the 2- to 3-m depth contours during November 1977.

		Northern Reference Area			Northern Nearfield Area			Southern Nearfield Area			Southern Reference Area		
		Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	
Total number of organisms collected in each jar	13	29	20	21	53	73	99	33	106	11	24	5	
Number of species collected in each jar	6	8	9	7	5	11	9	10	13	7	9	4	
Mean number of organisms per jar + one standard deviation	20.7 ± 8.02			49.0 ± 26.2			79.3 ± 40.3			13.3 ± 9.7			

Table 15. Estimates of the density of meiofaunal taxa at several sampling stations in the Calvert Cliffs region.

Meiofaunal Taxa	WS-1/1	CB-1/4	2- to 3-m Depth Contours		3- to 4-m Depth Contours		4- to 5-m Depth Contours		5- to 6-m Depth Contours		6- to 7-m Depth Contours		7- to 8-m Depth Contours		8- to 9-m Depth Contours		9- to 10-m Depth Contours	
			PP-1	UL1-1/8	RP-1/13	LB-11/5	CC-11/9	RP-11	WS-11/3	CC-11/10	RP-11	WS-11/3	CC-11/11	RP-11	WS-11/3	CC-11/11	RP-11	WS-11/3
Juvenile bivalves	1,974	219	-	-	439	658	-	-	219	-	-	-	-	-	-	-	-	-
Cyclopoid copepods	-	2,632	-	-	439	2,412	-	-	439	-	-	-	-	-	-	-	-	-
Harpacticoid copepods	1,974	56,798	3,947	3,947	2,412	7,237	-	-	-	-	-	-	-	-	-	-	-	-
Foraminifera	15,788	1,754	-	7,894	219	2,632	-	-	-	-	-	-	-	-	-	-	-	-
Nematodes	669,035	604,823	1,659,759	3,023,485	397,587	308,114	513,124	122,368	9,868	647,326	-	-	-	-	-	-	-	-
Oligochaetes	1,974	1,096	-	-	877	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracods	-	1,974	5,921	-	6,140	1,316	3,947	-	-	-	-	-	-	-	-	-	-	-
Juvenile polychaetes	-	658	1,974	-	219	2,193	-	-	-	-	-	-	-	-	-	-	-	-
Turbellaria	73,022	5,701	61,180	104,598	8,333	2,632	-	-	219	-	-	-	-	-	-	-	-	-

* Meiofaunal samples from these habitats were collected by taking 0.45 cm² cores from grab samples. Unfortunately, the pressure wave created by the hydraulic grab when deployed on soft sediments blows away the upper few millimeters of sediments in these habitats, so most of the meiofauna estimates from these samples are probably low.

Table 16. Average number of individuals per m^2 of meiofaunal taxa for various depth habitats in the Calvert Cliffs region during July and August 1978.

Meiofaunal Taxa	Depth Habitat		
	2- to 3-m	6- to 7-m	9- to 10-m
Juvenile bivalve larvae	2,635	293	-
Cyclopoid copepods	1,024	-	-
Harpacticoid copepods	20,395	951	-
Foraminifera	5,918	1,536	-
Nematodes	557,148	298,748	9,868
Oligochaetes	1,316	1,024	1,974
Ostracods	2,705	658	-
Juvenile Polychaetes	293	731	-
Turbellaria	29,019	1,609	-

Table 17. Observed and predicted mean oyster growth in the Calvert Cliffs region during 1977 and 1978.

Kenwood Beach				Plant Site				Cove Point			
Observed $\Delta Y(t+1)$ (mm)	Predicted $\Delta Y^*(t+1)$ (mm)	Difference Z ($\frac{in}{ft}$)	$\Delta Y(t+1)$ (mm)	Observed $\Delta Y^*(t+1)$ (mm)	Predicted $\Delta Y^*(t+1)$ (mm)	Difference Z ($\frac{in}{ft}$)	$\Delta Y(t+1)$ (mm)	Observed $\Delta Y^*(t+1)$ (mm)	Predicted $\Delta Y^*(t+1)$ (mm)	Difference Z ($\frac{in}{ft}$)	$\Delta Y^*(t+1)$ (mm)
<u>June-September 1977</u>											
Spat	28.10	26.55	5.5	26.40	25.22	4.5	29.70	25.39	14.5		
Seed	16.30	18.04	-10.7	15.90	16.94	-6.5	17.45	16.77	3.9		
Market	14.95	9.57	36.0	14.90	11.10	25.5	12.78	9.63	24.6		
<u>September-December 1977</u>											
Spat	5.75	11.89	-106.8	9.55	14.21	-48.8	12.03	19.03	-58.2		
Seed	6.88	8.89	-29.2	9.18	9.69	-5.6	8.30	14.02	-68.9		
Market	5.43	3.36	38.1	5.08	4.64	8.7	5.97	7.85	-31.5		
<u>June-September 1978</u>											
Spat	19.66	26.22	-33.4	22.80	24.66	-8.2	24.15	25.13	-4.1		
Seed	16.30	16.70	-2.5	19.38	16.84	13.1	10.42	16.78	-61.0		
Market	9.48	9.28	2.1	10.50	9.63	8.3	6.63	8.69	-31.1		
<u>September-December 1978</u>											
Spat	11.94	13.72	-14.9	14.22	14.75	-3.7	8.90	20.79	-133.6		
Seed	9.34	7.96	14.8	12.60	8.58	31.9	9.78	16.65	-70.2		
Market	7.57	4.50	40.6	8.00	4.58	42.8	7.24	9.10	-25.7		

Table 18. Average weight (mg) of nine-month-old soft-shell clams at sampling locations along the 2- to 3-m depth contours in the Calvert Cliffs region.

	Northern Reference Area	Northern Farfield Area	Northern Nearfield Area	Southern Nearfield Area	Southern Farfield Area	Southern Reference Area
Preoperational period November 1973 - August 1974	65.9	*	*	33.08	59.67	29.38
Operational period November 1976- August 1977	145.35	100.85	249.25	463.15	*	120.00

* Insufficient numbers of clams obtained at these locations to estimate average weight.

1. *Nereis succinea* (burrowing polychaete)
2. *Leptocheirus plumulosus* (tube-building amphipod)
3. *Streblospio benedicti* (tube-building polychaete)
4. *Corophium lacustre* (tube-building amphipod)
5. *Polydora ligni* (tube-building polychaete)
6. *Lepidacylides dyscritus* (burrowing amphipod)
7. *Eteone lacustris* (burrowing polychaete)
8. *Mya arenaria* (soft-shell clam, burrowing clam)
9. *Monoculodes edwardsi* (burrowing amphipod)
10. *Macoma balithica* (burrowing clam)
11. *Heteromastus filiformis* (tube-dwelling polychaete)
12. *Scaloplos fragilis* (burrowing polychaete)
13. *Mulinia lateralis* (cock clam, burrowing clam)
14. *Molgula manhattensis* (sea squirt, fouling organism)
15. *Balanus improvisus* (barnacle, fouling organism)
16. *Stylococcus ellipticus* (flatworm)
17. *Rhithropanopeus hirsutus* (mud crab)
18. *Crassostrea virginica* (American oyster)
19. *Merita nitida* (amphipod)
20. *Pectinaria gouldii* (tube-building polychaete)
21. *Scolecolepides viridis* (tube-building polychaete)
22. *Micrura leidyi* (burrowing proboscis worm)
23. *Eteone heteropoda* (burrowing polychaete)
24. *Diaquemene leucolena* (sea anemone, fouling organism)
25. *Parapionospio pinnata* (tube-building polychaete)

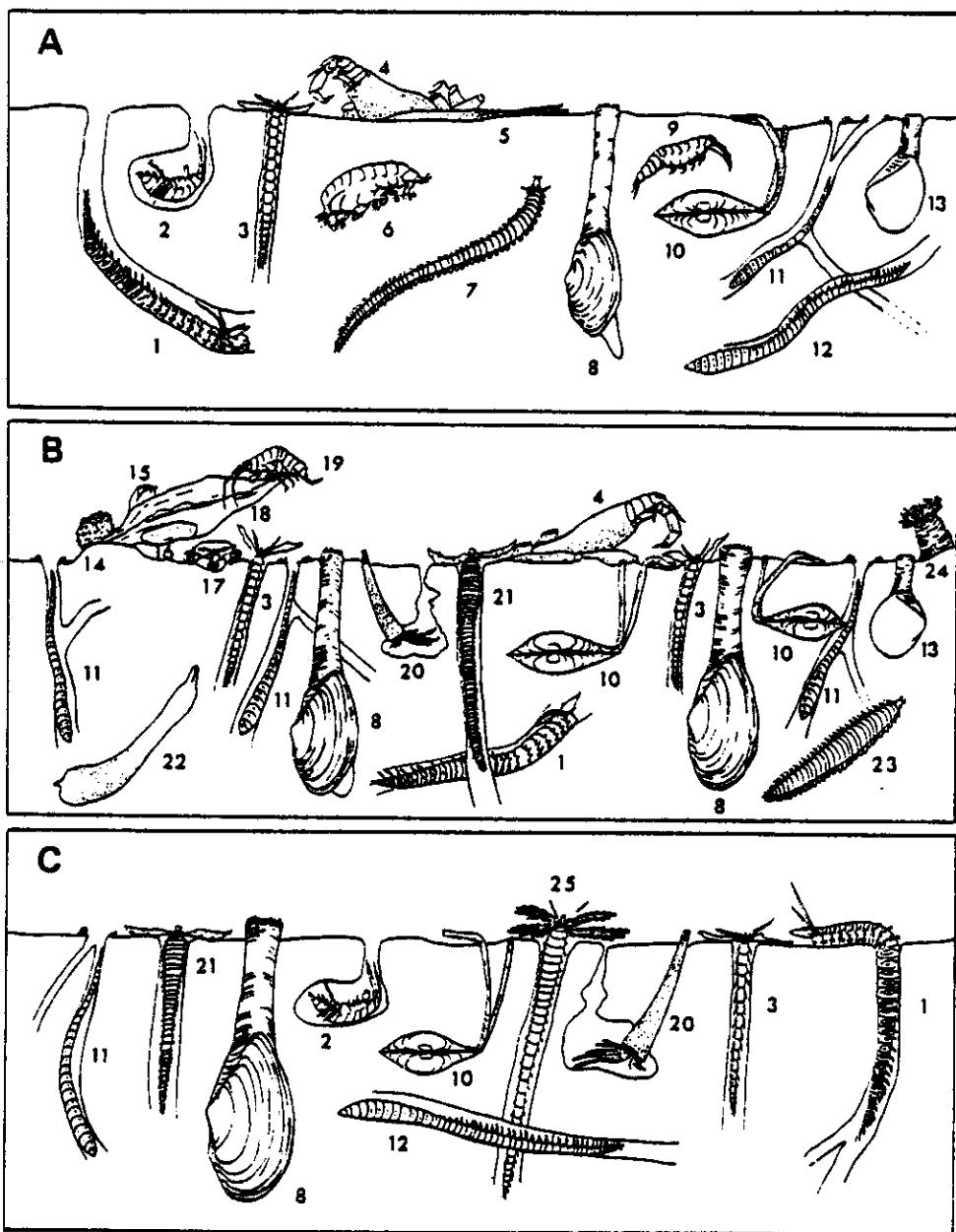


Figure 1. Macrobenthic communities that would inhabit soft sediments of the Calvert Cliffs region: A - nearshore sand community; B - transitional muddy-sand community; C - deep-water mud community (from Lippson et al., 1979).

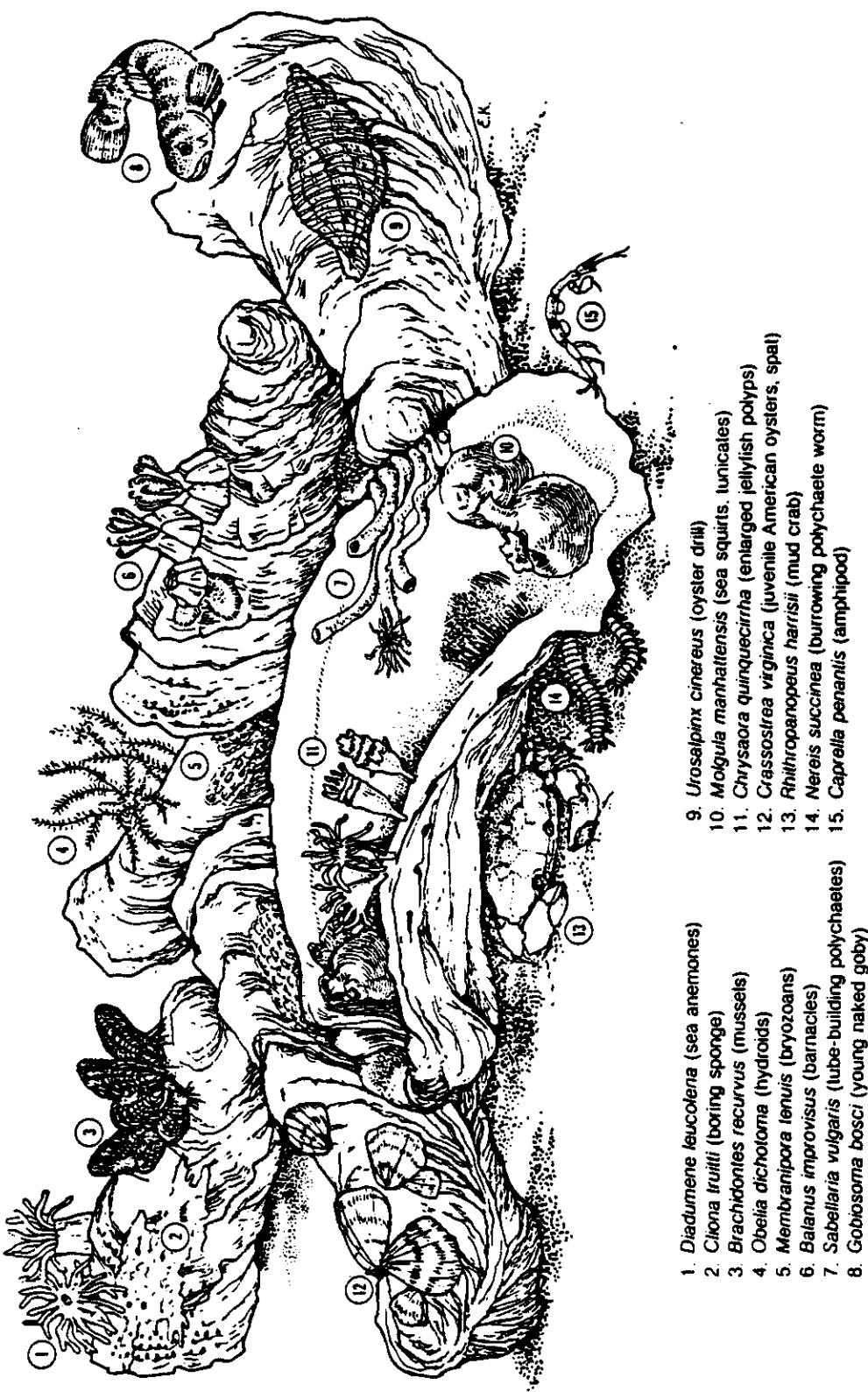


Figure 2. A representative community that would inhabit shell habitats of the Calvert Cliffs region (from Lippson et al., 1979).

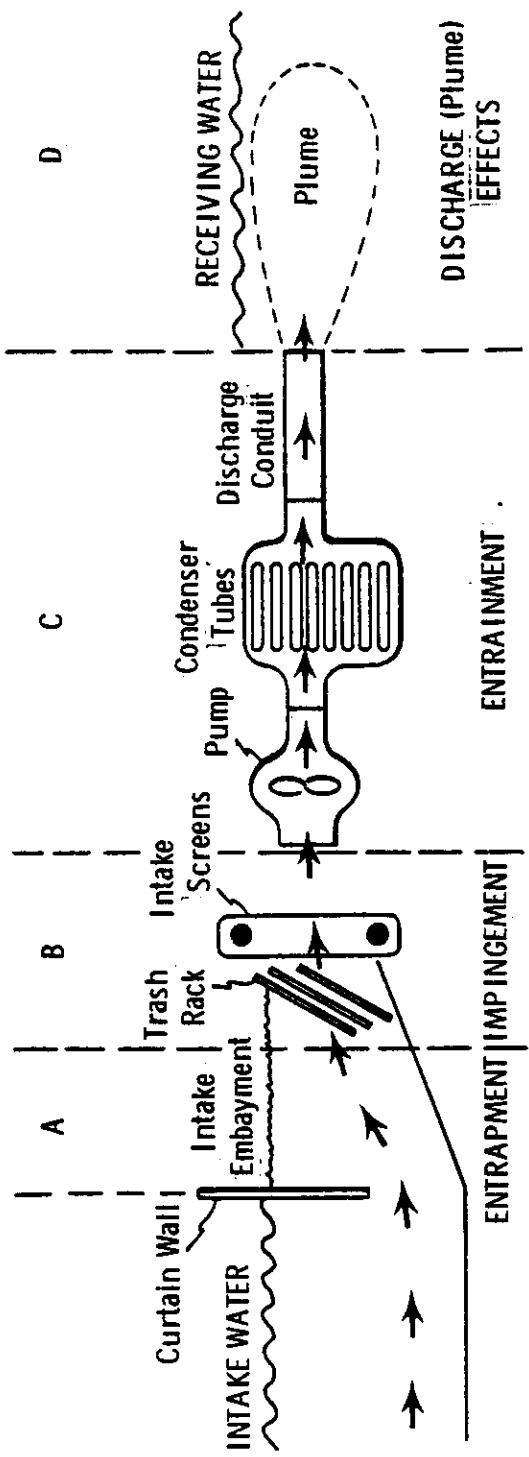


Figure 3. Path of cooling water flow through a power plant and locations of plant-organism interactions.

- Motile benthic organisms may be entrapped in the intake embayment and may suffer prolonged exposure to water of low dissolved oxygen content drawn from below the curtain wall.
- Organisms may be trapped on intake screens; the screens are rotated to wash the organisms from the screens back into the receiving water.
- Small organisms in the water column pass through the cooling system; they experience a temperature rise and shear and pressure forces during their transit through the cooling system.
- Organisms in the receiving water may encounter plume temperature rises and may be affected by the velocity of the discharge.